Predicting the Evolution of Tidal Channels in Muddy Coastlines

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LONG-TERM GOALS

- To quantify the relationships between resuspension of fine material in the shelf by wind waves, tidal channels hydrodynamics, and sediment supply to coastal marshes.

- To develop predictive, high-resolution models for the hydrodynamics and sediment dynamics of tidal channels in muddy coastal environments

- To develop methods to predict the long-term evolution of tidal channels in muddy coastlines as a function of sediment availability, hydrodynamics, and climate change.

OBJECTIVES

• Measure the supply of sediments to a Louisiana salt marsh as a function of wind waves.

• Apply, test, and validate a high resolution hydrodynamic-sediment transport model in a Louisiana marsh and determine the short-term evolution of the tidal channels and the supply of sediments from the shelf.

• Integrate the short-term results of the high resolution numerical model in already developed long-term models of tidal channel evolution.

• Link the transport of sediments to salt marshes via tidal channels to the resuspension of fine sediments in the adjacent shelf.

• Compare the results of the MURI project “Mechanisms of Fluid Mud Interactions under Waves” to measurements of sediment concentration in a nearby marsh channel.

• Share and merge the model and results with those of the MURI Research Group.

APPROACH

Field Component: We will focus on the Little Constance Bayou, a creek in the Rockefeller State Wildlife Refuge (fig. 1) to characterize the fluxes of sediments from the shelf to the marshes. We deployed a Nortek ADCP with an Acoustic backscattering System at the mouth of the creek to measure tidal elevation, water velocity, and concentration of suspended sediment in time. A Sontek ADV was deployed in the bay in front of the channel mouth to record wave characteristics during the studied period.

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High resolution modeling component: In order to integrate field measurements with long-term evolution models we have developed a geomorphological theory of tidal basin response to describe specific characteristics of tidal channel hydrodynamics. From point measurements of velocity and sediment concentration at the channel outlet we can have a first estimate of the morphological characteristics of the muddy coastline. Vice versa, the morphology of the intertidal area can provide us a first estimate of tidal fluxes and sediment fluxes in the channels that can be used in long term morphodynamic models of marsh evolution.

Integration of short-term high-resolution models with long-term simplified models:
In recent years we have developed a suite of morphological models that quantify the response of salt marshes to changes in sea level, sediment supply, vegetation, and substrate characteristics. The models are able to simulate the feedbacks between morphology and wave propagation in salt marshes (Fagherazzi et al. 2003, Rinaldo et al. 1999), the long-term variations in channel cross section (Fagherazzi and Furbish 2001, D'Alpaos et al. 2006) The development of the channel network (Fagherazzi and Sun 2004, D'Alpaos et al. 2005), the feedbacks between vegetation and sedimentation (Mudd et al. 2004) and the repartition of intertidal areas between tidal flats and salt marshes (Fagherazzi et al. 2006a; Fagherazzi et al. 2006b).

All these models rely on simplified, physically based hypotheses for tidal flow and sediment transport. Our long-term plan is the integration of short-term and long-term models in the same framework.

WORK COMPLETED

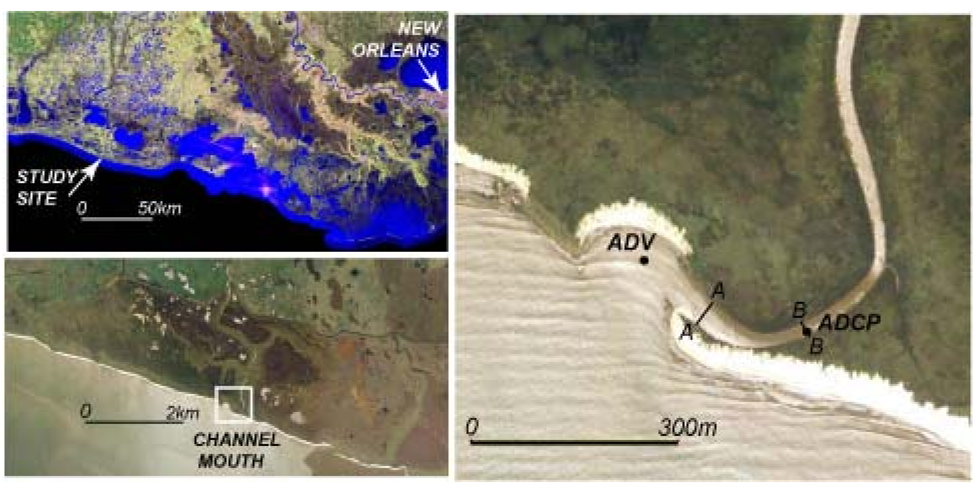

Figure 1 Location of Little Constance Bayou in the Rockefeller National Wildlife Refuge, Louisiana. The location of the deployed ADV and ADCP is shown in the figure on the left.

We deployed a Sontek ADV vertically mounted on a tripod just in front of the channel mouth (see Fig. 1) and measured the wave climate every hour from 12/17/07 at 3pm to 1/14/08 at 10 am and from 01/18/08 at midnight to 02/20/08 at 15pm. The frequency of the wave burst was at 5 hertz and measured 2048 water elevations.
Within the tidal channel we deployed a Nortek ADCP and measured tidal elevation and water velocity every half an hour during the same period than the ADV measurements.

We use the sixth interval of the ADCP profiler, which measure the velocity between 0.3 and 0.4 m, for the channel velocity. We use the amplitude of the ADV signal between 0.3 and 0.4 m as a proxy for sediment concentration. The amplitude signal was calibrated with sediment concentration samples collected in situ.

Figure 2 Studied tidal channel in the Rockefeller National Wildlife Refuge. The Nortek ADCP was deployed at the channel bottom near the boat location.

RESULTS

The data collected were organized in an hourly time series. In Fig. 4 we report an example of the data resolution from Dec. 18 to Dec 24 2007. A moderate storm hit the Louisiana coast from Dec 20 to Dec 24, producing two distinct wave events on Dec. 20 and Dec. 22 2007, with significant wave height between 0.7 and 1m. The first event occurred for wind directions from South whether the second was produced by winds blowing from South West perpendicular to the coastline direction. The wind speed seemed higher for the second event (Fig. 4a) even though the lack of offshore data warrants a precise assessment of wind conditions. On Dec 22 SSW winds produced a moderate storm surge both at Calcasieu Pass (difference between predicted and measured tide in Fig. 4c) and at our study site (Fig. 4f). The storm surge increased water elevations in the channel (Fig. 4f), tidal velocities (Fig. 4g), and suspended sediment concentrations (Fig. 4h). To investigate the relationship between sediment concentration, tidal elevation, wave height, and flow velocity in the channel we have divided the data in six different groups, as a function of tidal elevation and flow velocity in the channel. The six groups roughly correspond to six different stages in the tidal cycle (Fig.4). For each stage we run a correlation between sediment concentration in the channel and wave height, flow velocity, and tidal elevation. Sediment concentration in the channel appears highly correlated to wave height, particularly during flood events and during high slack water. It is easy to envision that sediment resuspended by waves near the channel mouth is then moved in the channel during flood.

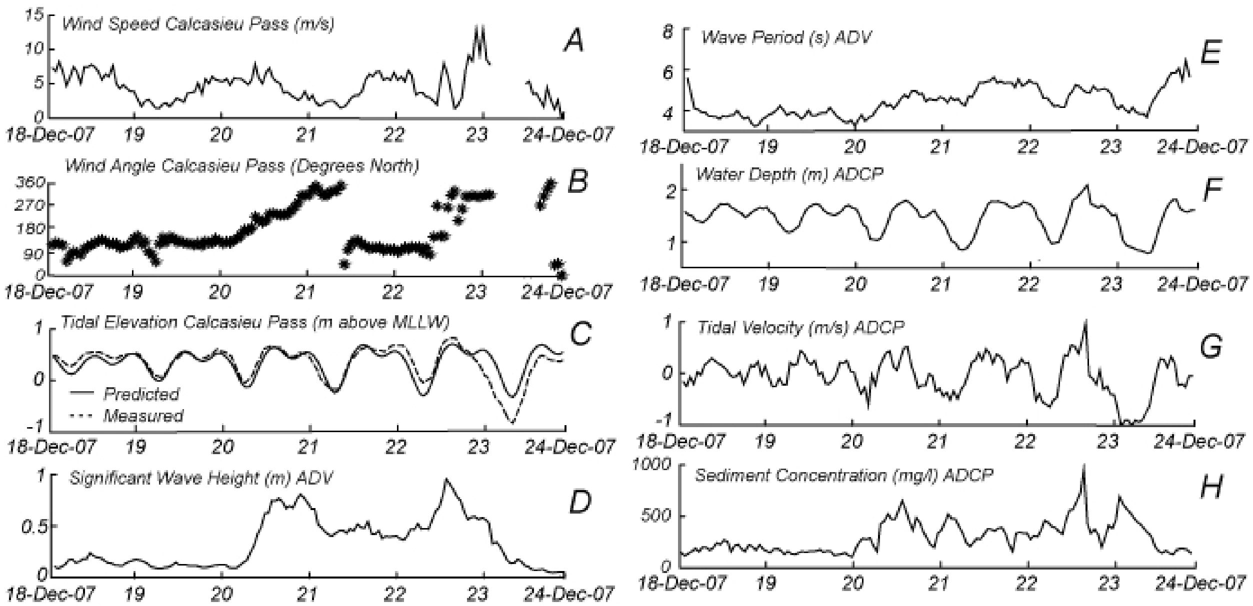

Figure 3 Measurement of hydrodynamic and sediment parameters at the study site during the period Dec 18 - Dec 24 2007: a) wind speed, b) wind direction and c) measured and predicted tidal elevations at the NOAA station in Calcasieu Pass, d) significant wave height and e) wave period at the channel mouth, f) water depth g) tidal velocity and h) sediment concentration in the tidal channel.

The transport of sediment continues even during high slack water, but with a lower correlation and extends also to the first part of the ebb, probably because the combination of low velocities and proximity of energetic condition in the bay are still influencing the sediment concentration in the channel. During ebb the sediment concentration is not influenced by the wave climate, since the tidal flow is transporting sediment from the marsh interior to the ocean. During this stage there seems to be a relationship between sediment concentration and channel velocity, with high (negative) velocities promoting elevated bottom shear stresses that favor sediment resuspesion in the channel. Similarly, during flood it appears to be a positive correlation between flow velocity and sediment concentration, evidence of a combined effect of currents and waves in the resuspension of bottom sediments. We also detect a weak influence of water elevation on sediment concentration during the ebb phase, with high sediment concentration for low tidal elevation. This is probably due to sediment fluxes front the marsh banks during the late stages of the ebb

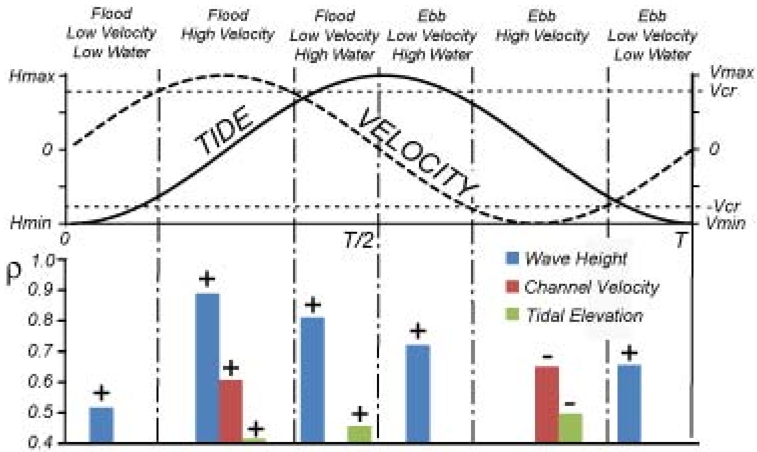

Figure 4. Correlations between sediment concentration in the channel, tidal elevation, flow velocity, and wave height in the bay. The data are grouped in six different tidal stages as a function of flow velocity and water elevation.

IMPACT/APPLICATIONS

The collected data will help assessing the navigability of tidal channels in denied areas. Moreover, the characterization of wave climate along a muddy coast will provide useful information for navigation in very shallow water and landing. Finally, the feedbacks between tidal channels and waves will provide information on the origin of marsh sediments and their characteristics.

RELATED PROJECTS

The proposed research is designed to synergistically complement the already funded MURI project "Mechanisms of Fluid Mud Interactions under Waves" (http://www.ce.jhu.edu/dalrymple/MURI/). The MURI project studies the interactions between waves and muddy bottomsets in the shelf in front of the Rockefeller State Wildlife Reserve. In this project we will measure the sediment concentration in nearby tidal channels during the same period, and use this information to tune a model for tidal channel evolution.

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